Further Analysis of Thermal Control Coatings on MISSE for Aerospace Applications

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Many different passive thermal control materials were flown as part of the Materials on International Space Station Experiment. Engineers and scientists at the Marshall Space Flight Center have analyzed a number of these materials, including Z93P zinc oxide/potassium silicate coating, YB-71P zinc orthotitanate/potassium silicate coating, NZOT, which is a low-cost alternative to YB-71P, several electrically conductive/static dissipative thermal control coatings, as well as black coatings for part marking and automated rendezvous and capture.

These were exposed to the low Earth orbital environment of atomic oxygen, ultraviolet radiation, thermal cycling, and hard vacuum, though atomic oxygen exposure was very limited for some samples. Results from the one-year exposure of MISSE-3 and MISSE-4 are compared to the four-year exposure of MISSE-1 and MISSE-2. Solar absorptance, infrared emittance, and mass measurements indicate the durability of these materials to withstand the space environment. The effect of contamination from an active space station on the performance of white thermal control coatings is discussed.

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26 Different coatings from Alion Science were flown on the Materials on International Space Station Experiment (MISSE)

- Location on MISSE-3 and 4
- Environmental Exposure
- Effects on Coatings
  - Thermal Control Coatings
  - Electrically Conductive/Static-Dissipative Coatings
  - Comparison between 1-year and 4-year exposures
- Discussion and Conclusions

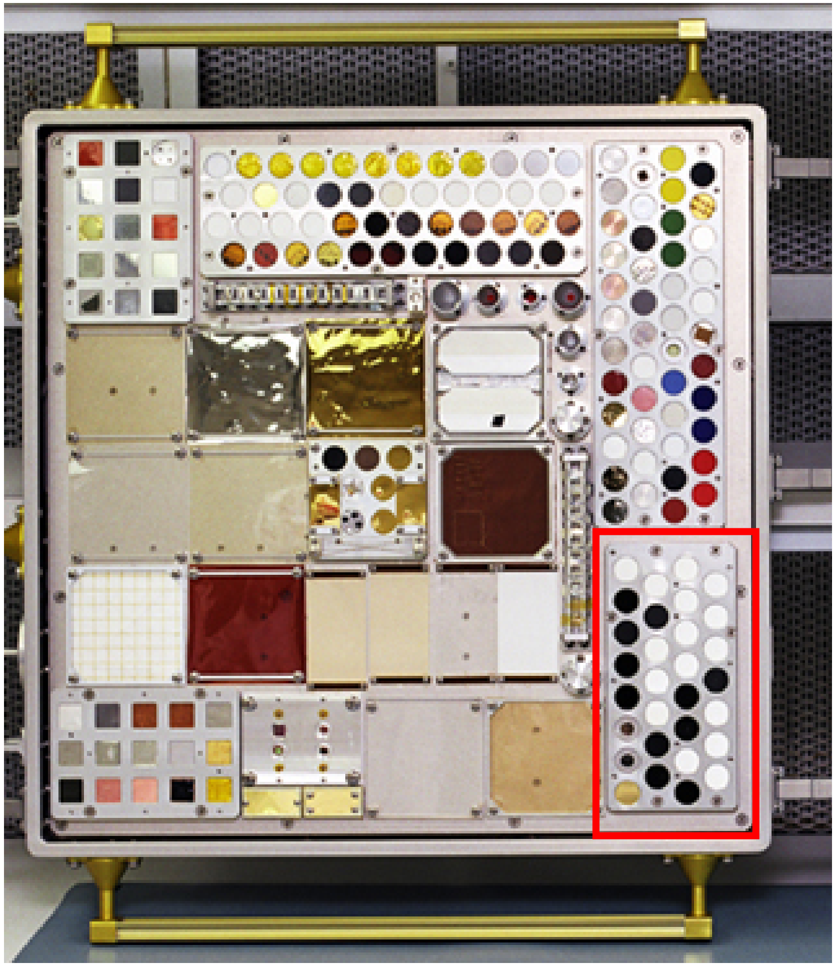


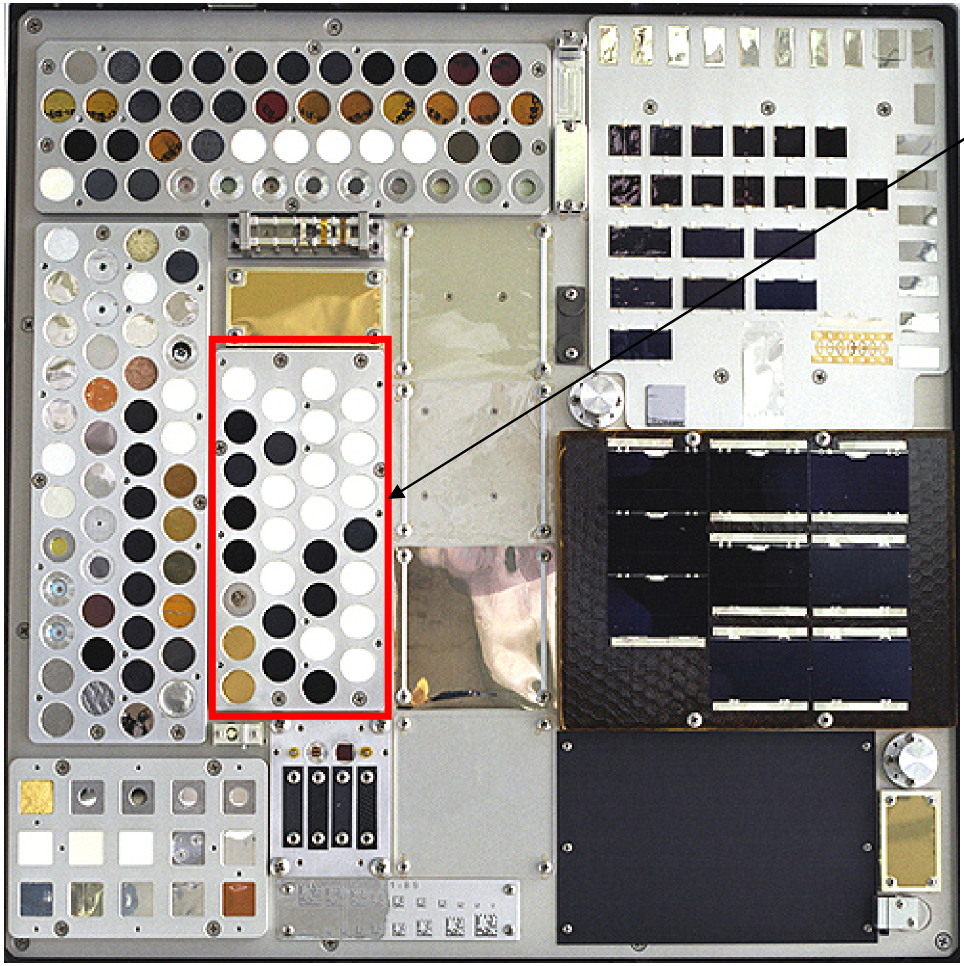
Photo courtesy of Langley Research Center

Tray D4
Located on ram-facing side of MISSE-3

1.2 to 1.3 x 10^{21} atoms/cm^2 AO fluence, as measured by polymer mass and thickness loss

~1,750 ESH calculated solar exposure

"Estimated Environmental Exposures for MISSE-3 & MISSE-4"
Finckenor, Pippin and Kinard



Tray D6

On nominally wake-facing side of MISSE-4

3.6×10^{20} atoms/cm^2 calculated AO fluence

~900 ESH calculated solar exposure

"Estimated Environmental Exposures for MISSE-3 & MISSE-4"
Finckenor, Pippin and Kinard

Photo courtesy of Langley Research Center

Post-Flight

D4 (Ram)

D6 (Wake)

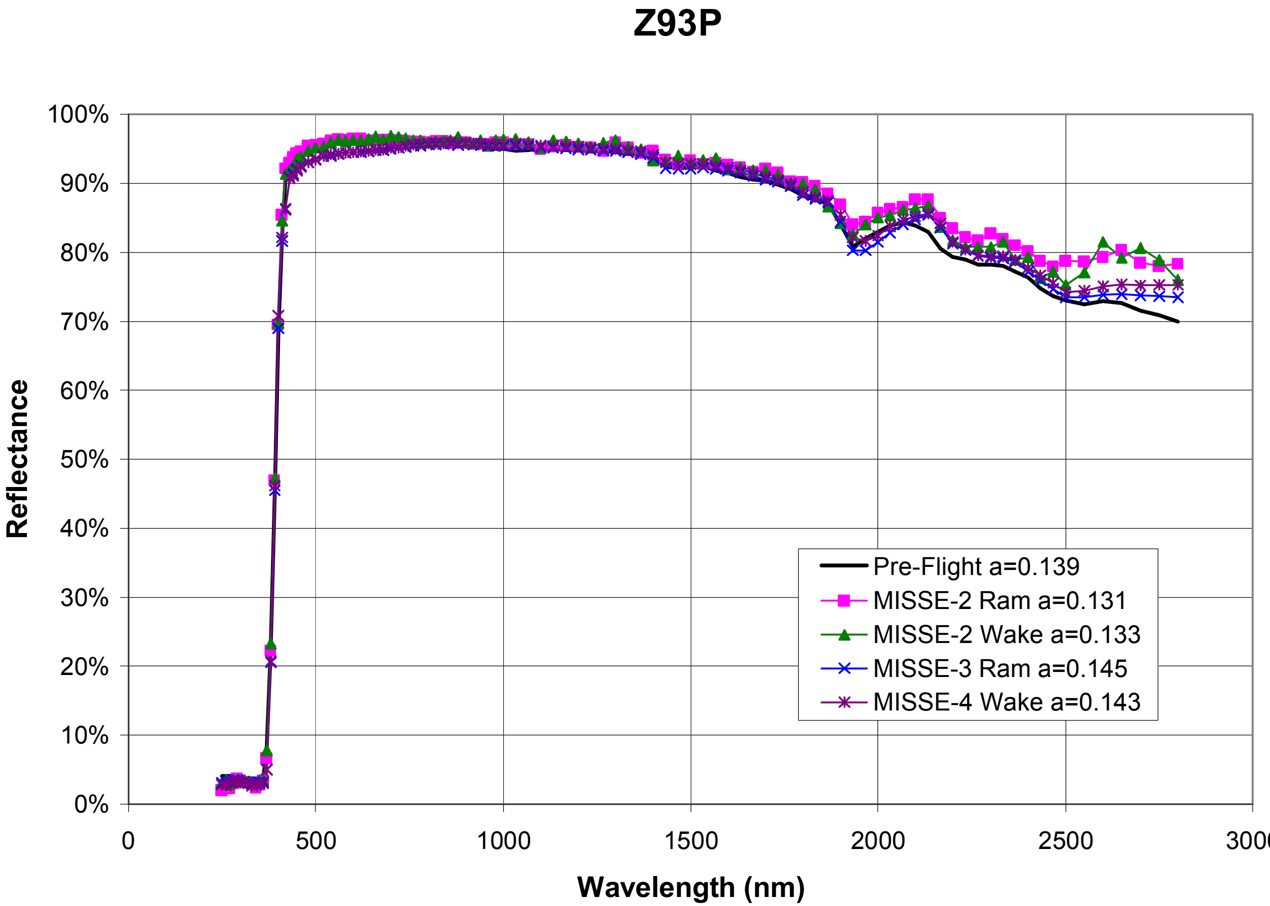
Alion Thermal Control Coatings on MISSE-2

- Inorganic ceramic water based coatings, conductive and non-conductive

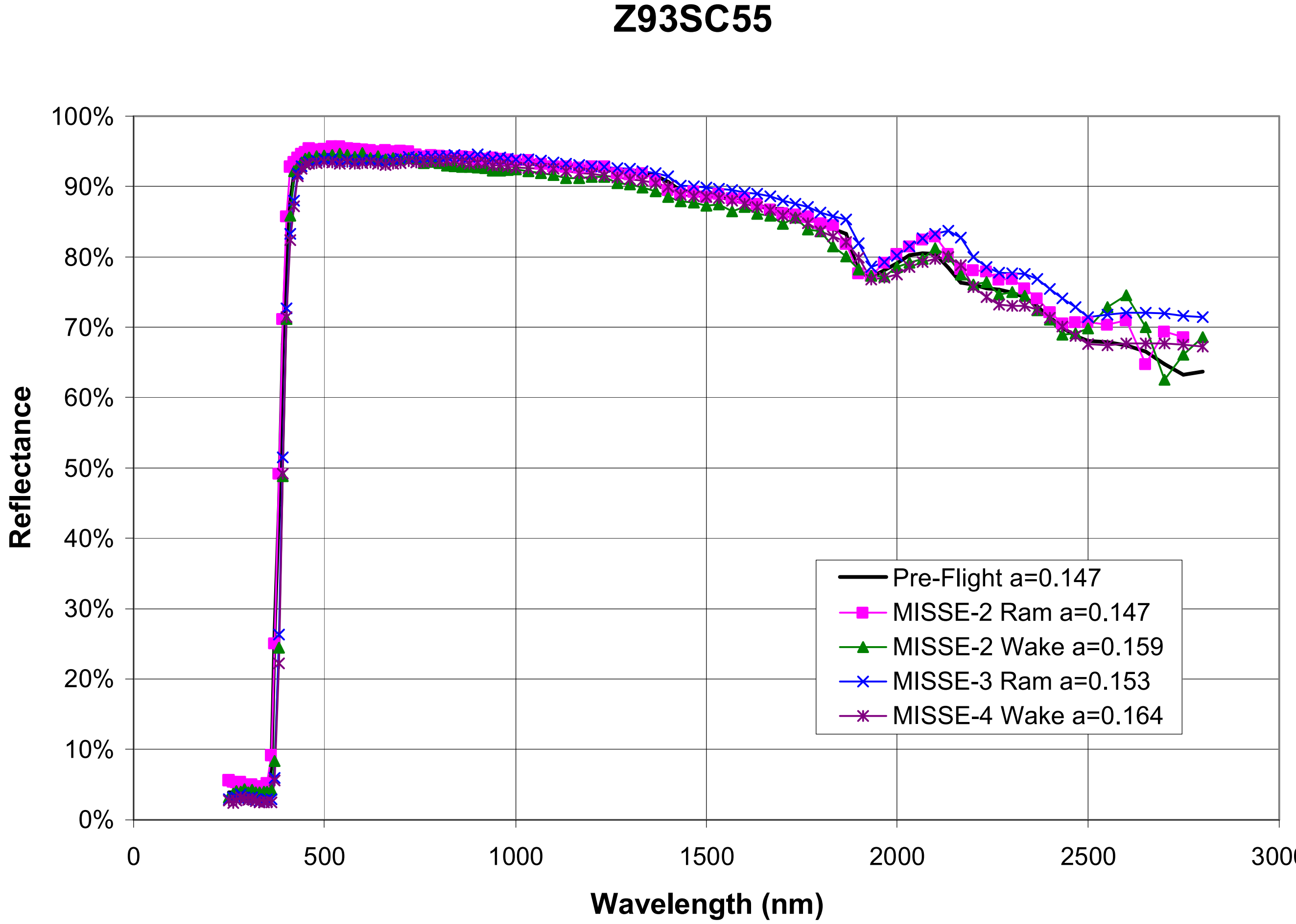
    -Z-93P, Z-93SC55, Z-93C55, YB-71P, YB-71C

- Flexible white organic coatings: conductive and non-conductive
    -S13GP:6N/LO-1, DS13N:6N/LO-HP(WCFB),
    S13GP:6N/LO-HP, S13GP/HSCT
- Inorganic ceramic water based coatings: conductive and non-conductive
    -MH21:IP, MH11ZP, MH55ICP, BGDH52
- Flexible black organic coatings: conductive and non-conductive
    -D21:6N/LO, D21:6NC/LO, MH2200, MH216NC/LO,
    MH21:6N/LO, BG808, MH41:6NCBLO
- New ceramic water based zinc-orthotitanates: conductive and non-conductive

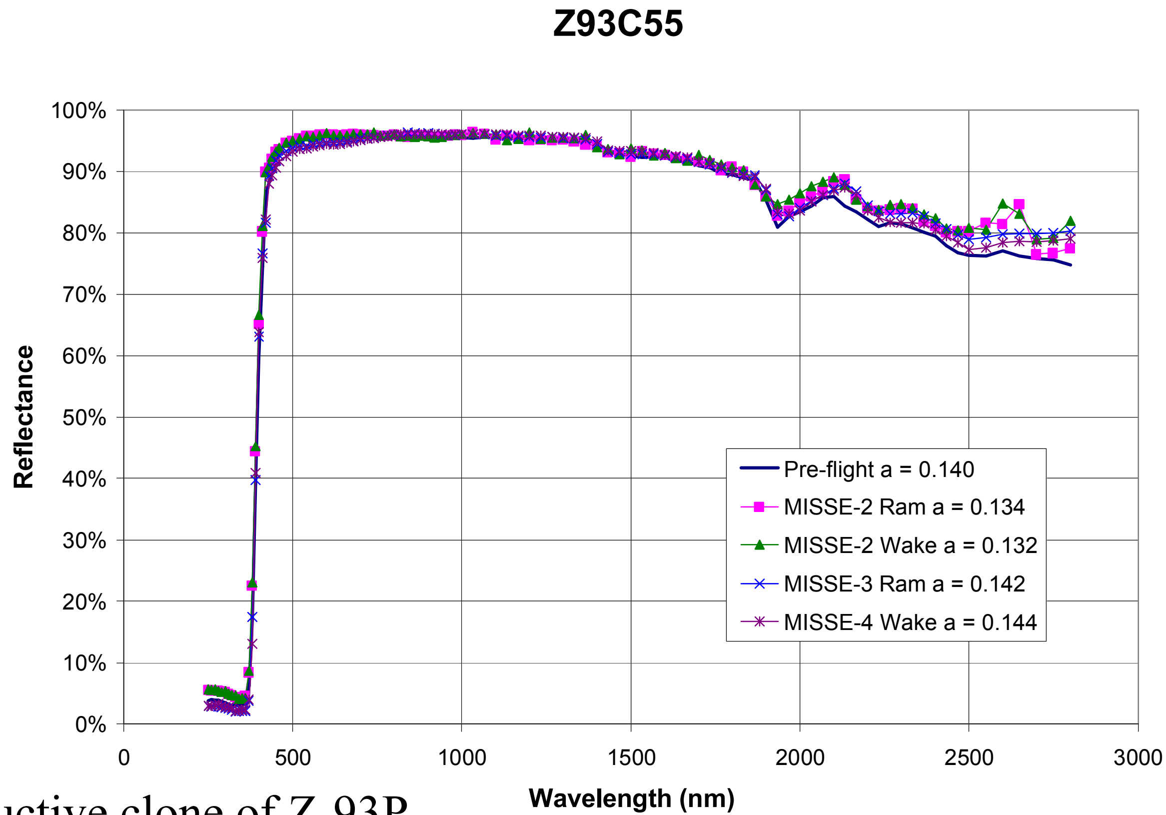
    -NZOT-P & DNZOT-P



- Calcined ZnO + silicate/water binder solution
- During its 40+ years of existence, Z-93/Z-93P has been used in many flight applications.
- Performance in Aerospace and AFRL/SCEPTRE exposure facilities are outstanding.
- Performed exceptionally well on Long Duration Exposure Facility (LDEF) 69 months in space.

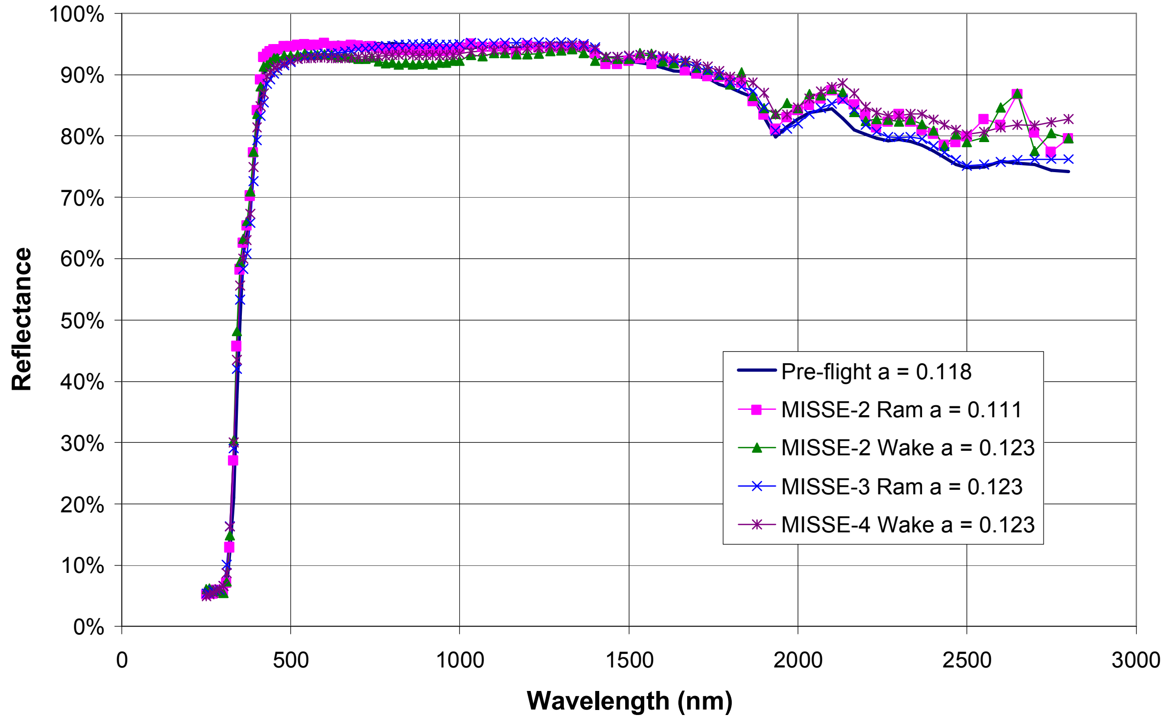


- Micro-encapsulated ZnO with a doped hybrid silicate/water binder solution.
- Used on CXD Radiators of GPS-Block IIR (1996-1999)
- Surface resistivity = 10ˆ7 to 10ˆ8 ohms/square

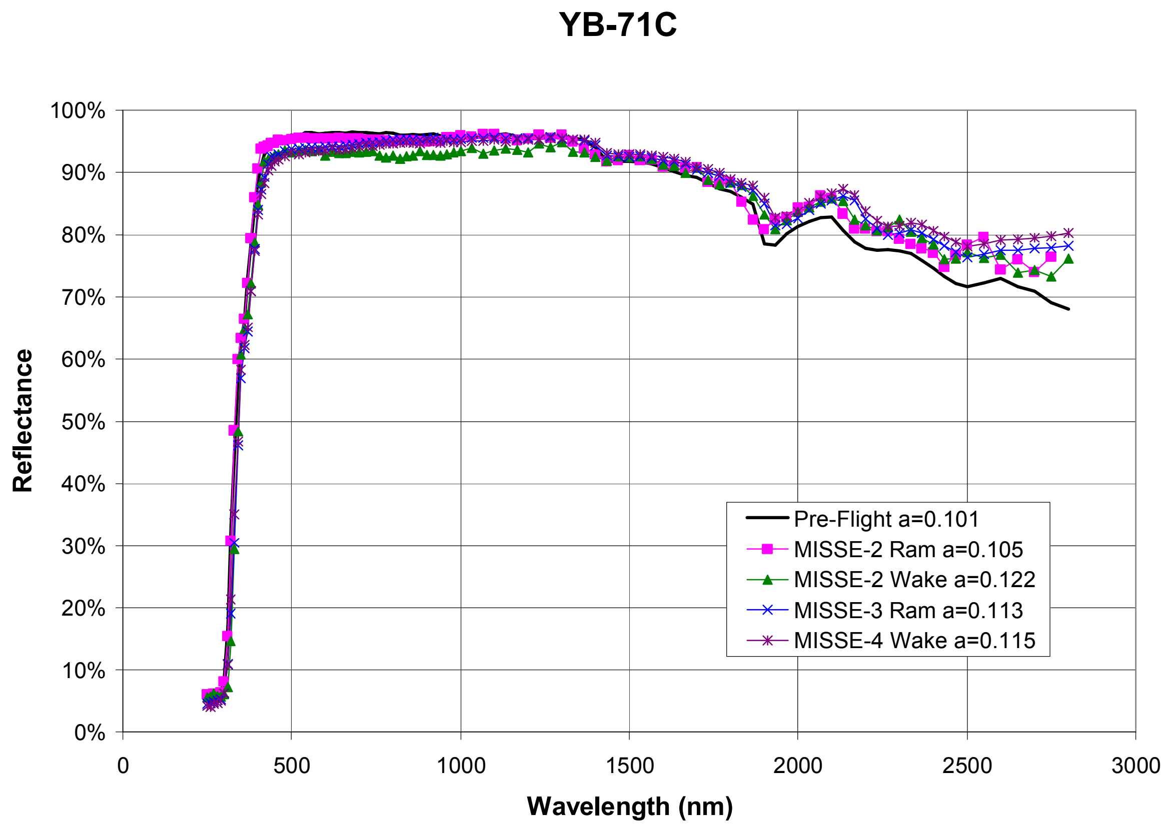


- Conductive clone of Z-93P.
- Applied on various commercial and government satellites.
- Surface resistivity = 10ˆ6 to 10ˆ8 ohms/square
- Submitted to AFRL on "Improved Thermal Control Coatings" research project.
  - USAF SCEPTRE Test 04QV01: Beginning of Life (BOL) $\alpha = 0.147$; End of Life (EOL) $\alpha = 0.187$

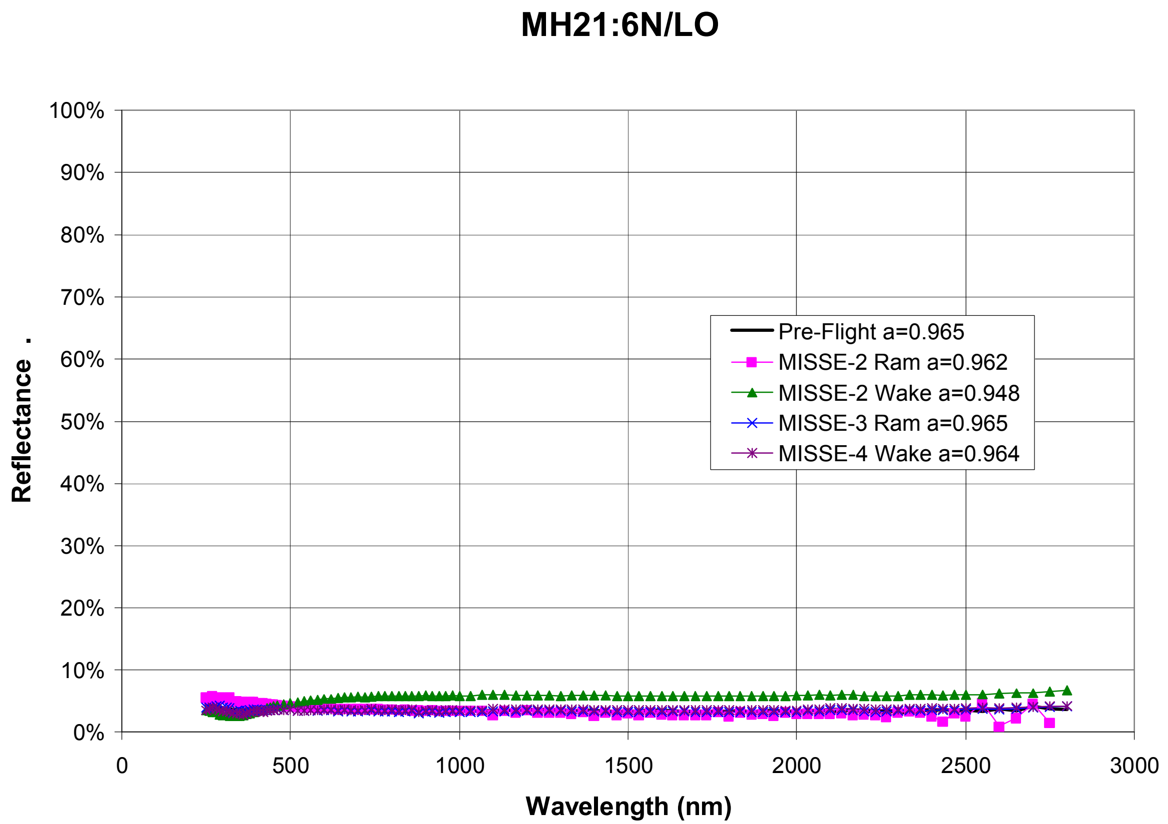
YB-71P



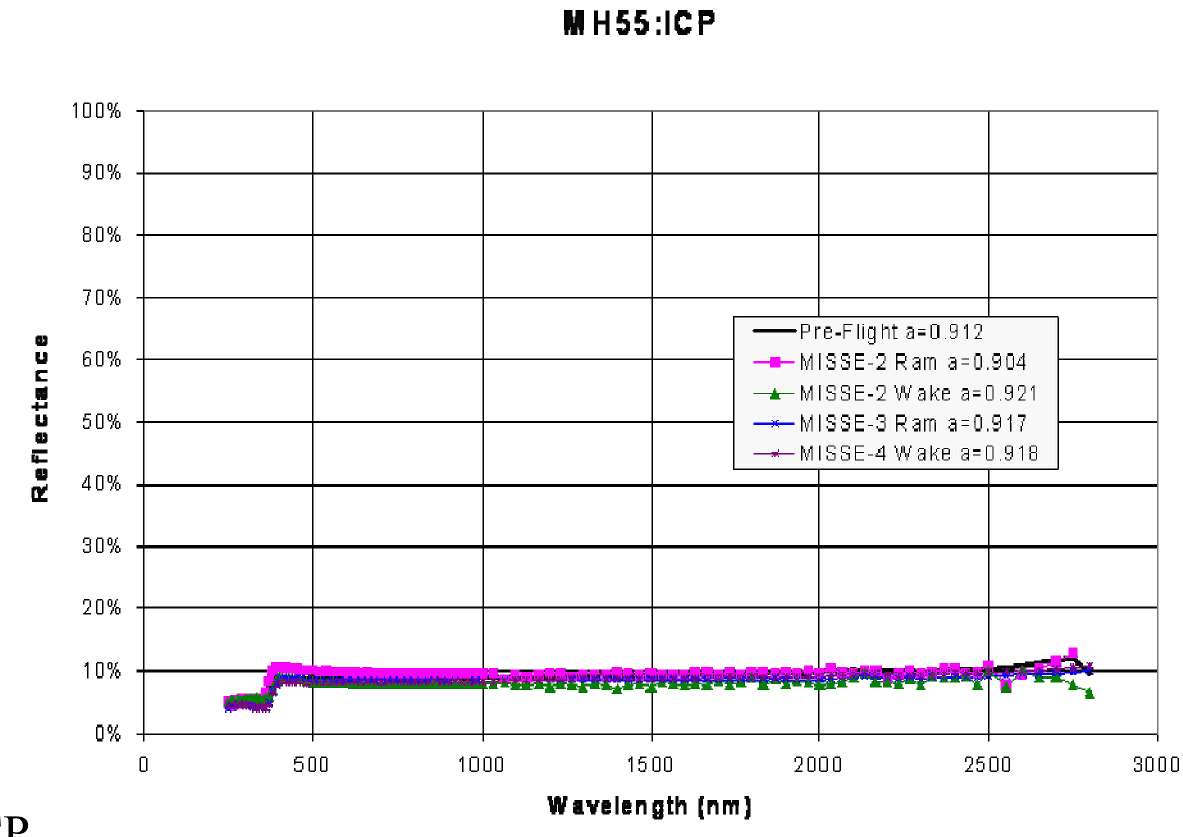
- Zinc-orthotitanate (ZOT) pigment in a silicate/water binder solution.
- Over 40 years of application in the aerospace community.
- Extensive testing performed at Aerospace Corp, Aerojet Geosynchronous Calorimetry Data (Ahern 1983), and USAF/SCEPTRE.
- Submitted to AFRL on "Improved Thermal Control Coatings" research project.
  - USAF SCEPTRE Test 04QV01 (287 hrs): Beginning of Life (BOL) $\alpha = 0.109$; End of Life (EOL) $\alpha = 0.135$; $\Delta = 0.026$



- ZOT pigment with a doped hybrid silicate/water binder solution.
- Conductive clone of YB-71P created for MISSE experiments.
- Material not officially offered for sale.



- Extensive testing at GSFC (NASA TM-100768 “An Evaluation of Two Flat-Black Silicone Paints for Space Application”
- Also tested at Aerospace Corp for 2000 ESH.
- Currently used on many commercial and government satellites
- Maintained optical properties on both D1 and D2 trays



MH55 ICP

- Conductive black paints with silicate/water binder
- Used currently on radiator manifolds on ISS
- Surface resistivity = 10^6 to 10^7 ohms/square
- Tested at Aerospace Corp. with no α change after 2000 ESH UV radiation
- Maintained optical properties on both D1 and D2 trays

Other Alion Black Paints

Black paints with siloxane binder

- D21:6N/LO
  - New, less expensive formulation of MH21:6N/LO
  - Maintained α of 0.96 – 0.97 on all four trays.
  - Currently used on many commercial and government satellites
- BG808 or BG/LC
  - Less expensive silicone, can also use less expensive pigment for large scale terrestrial app.
  - Maintained optical properties on all four trays

Alion Black Paints (cont'd)

Black paints with siloxane binder

- MH2200
  - Formerly ECP2200.
  - Optical absorber coating with terrestrial and space applications. Needs 450 ^{o}F bakeout.
  - Maintained α of 0.96 on all four trays.

Alion Black Paints (cont'd)

Conductive black paints with silicate/water binder

- MH11ZP
  - Clone of MH55ICP with "off the shelf" pigment
  - Surface resistivity = 10^7 ohms/square
  - Some fading of MISSE-2 ram-exposed sample
- BGDH52
  - Electrically conductive clone of MH21IP
  - Surface resistivity = 10^7 ohms/square
  - Fading of both one-year and four-year samples

Alion Black Paints (cont'd)

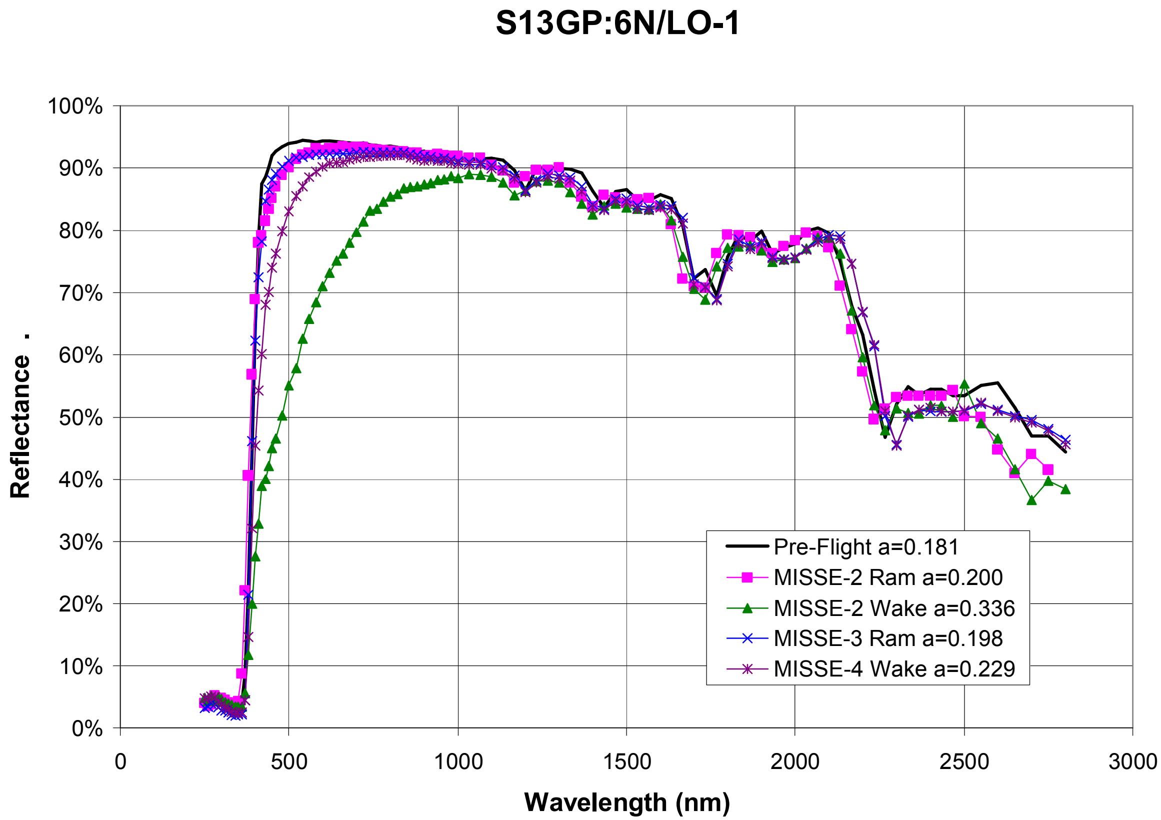
Conductive black paints with organic binder

- MH21:6NC/LO
  - Electrically conductive version of MH21:6N/LO
  - Surface resistivity = 10^7 to 10^9 ohms/square
  - All samples maintained $\alpha = 0.95$ or better.
- MH41:6NCB/LO
  - Also conductive version of MH21:6N/LO
  - Surface resistivity = 10^8 ohms/square
  - Also maintained optical properties

Alion Black Paints (cont'd)

Conductive black paints with organic binder

- D21:6NC/LO
  - New formulation of MH21:6NC/LO
  - Surface resistivity = 10^9 ohms/square
  - All four exposed samples maintained $\alpha = 0.96$ or better.



- White flexible organic TCMS with a long history of performance in aerospace.
- Inexpensive, user friendly, and easily cleaned, and reapplied.
- Extensive testing at Aerospace Corp. and AFRL/SCEPTRE
- Based on LDEF, S13GP:6N/LO-1 performed better than expected on D1 Tray and as expected on D2 tray.

Other Alion White Paints

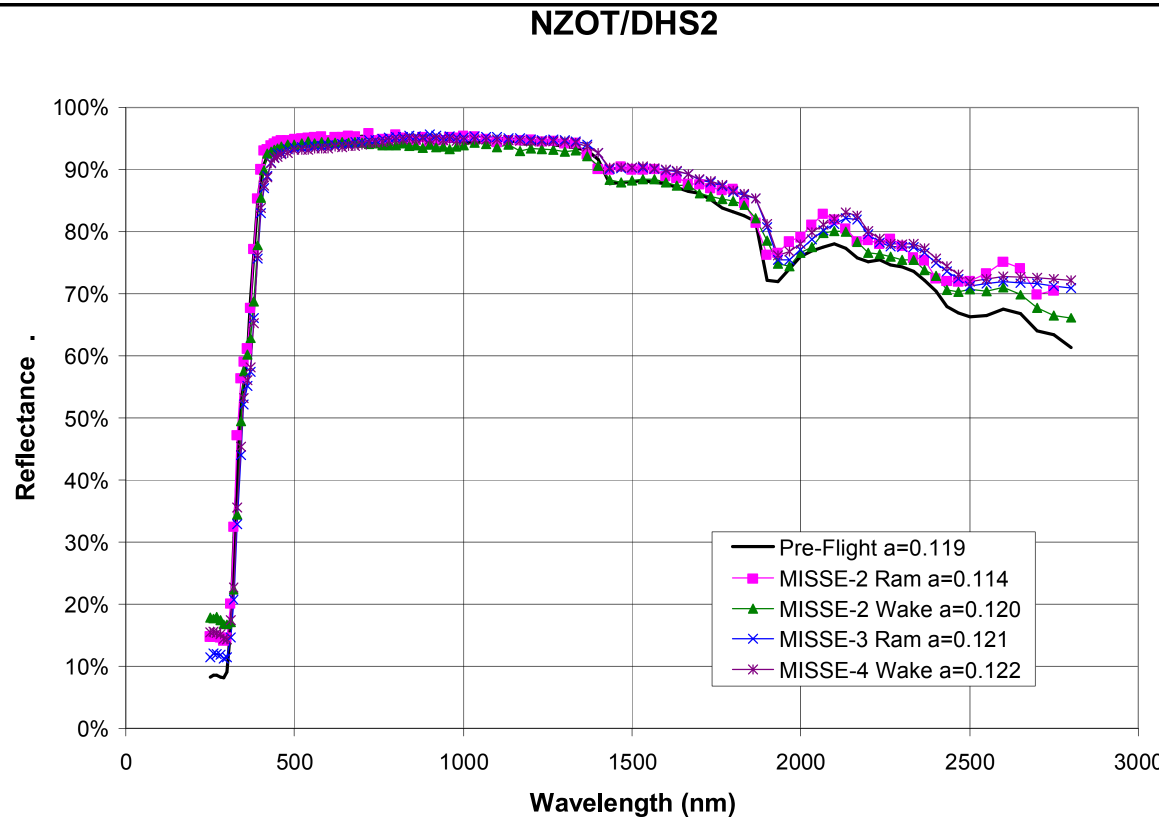
White paints with organic binder

- S13GP/LO-1
  - Material was retain from 2 year old stock
  - Material performed better than expected on ram trays and slightly below expectations on wake
  - Performance indicates fresh material performs best and 6 month shelf life is reasonable.
- S13GP:6N/LO-HP
  - Clone of S13GP:6N/LO-1
  - Higher mass loss
  - No change in α for ram-facing samples
  - Increase in α for wake-facing samples

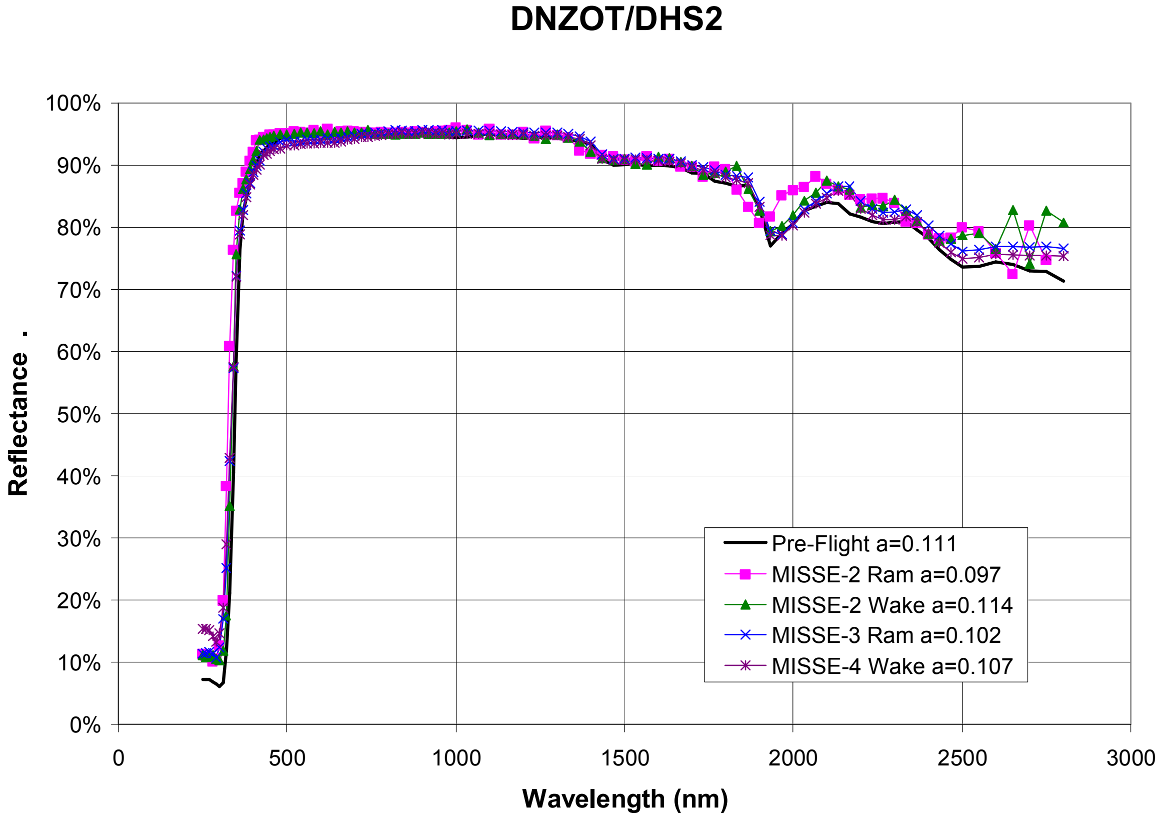
Other Alion White Paints

White paints with organic binder

- S13GP/HSCT or S13GP/LC
  - Originally developed as aircraft paint with potential for use in LEO
  - Wake-facing samples darkened due to UV
- DS13N:6N/LO-HP
  - Conductive clone of S13GP:6N/LO-1
  - Some mass loss due to high PBR
  - Surface resistivity of 10^7 to 10^8 ohms/square
  - Wake-facing samples darkened due to UV



- Developed as a less expensive version of YB-71P, and also eliminates any batch to batch variability that may have effected YB-71P in the past.
- Tested multiple times at AFRL/SCEPTRE on project “Improved Thermal Control Coatings” test 04QV01:
  - 287 hrs., ~775 ESH, 10^-7 torr, and total electron fluence=1.0x10^16 e-/cm²/sec
  - Produced a BOL $\alpha = 0.091$ and an EOL $\alpha = 0.128$, $\Delta\alpha = 0.037$



- Conductive clone of NZOT/DHS2, developed as a less expensive version of YB-71C, and also eliminates any batch to batch variability that may have affected YB-71C in the past.
- Also tested multiple times at AFRL/SCEPTRE
  - 287 hrs., ~775 ESH, 10^-7 torr, and total electron fluence=1.0x10^16 e-/cm²/sec
  - Produced a BOL α = 0.100 and an EOL α = 0.129, $\Delta\alpha$ = 0.029
- Surface resistivity of 10^6 ohms/square.

Conclusions: Alion Science and Technology Coatings

- All inorganic/ceramic materials, both whites and blacks performed well on the MISSE experiment in LEO {AO+UV} environment.
- All of Alion's coatings currently on the company's price list performed as expected or better in the MISSE experiment. All products also pass the ASTM-E595 outgassing test.
- YB-71P displayed excellent EOL properties with no yellowing or degradation in α observed.
- NZOT/DHS2 and DZOT/DHS2 performed beyond expectations and can provide cheaper alternatives to YB-71P and YB-71C.
- More darkening seen with S13G coatings for four-year exposure than one-year exposure, otherwise consistent results between flights.